ELECTRICITY

IN GENERAL PRACTICE

BOLTON TOMSON

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ELECTRICITY IN GENERAL PRACTICE.

BY

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PREFACE.

A MEDICAL man engaged in general practice can utilize electricity in a number of different ways, as in the treatment of disease by the constant and interrupted current, for the cautery, for lighting (as in the endo-cystoscope), for electrolysis, and for the electro-magnet. Almost every known form in which electrical force can be exhibited finds its application in some special department of medical or surgical work. Obviously the value of electricity, as an agent for combating disease, is immense; yet it must be admitted that it has not so far attained to that universal use which one would, *à priori*, have been led to expect. By way of explanation, it must be considered that the difficulties attending its application necessarily increase in proportion to the number of purposes to which it has to be adapted.

For every one of the divisions enumerated above we find some special form of battery offered for sale. These are generally complicated in structure, correspondingly expensive, and closed in in such a manner that any slight defect necessitates a return to the instrument-makers for repair.

Apparatus of this kind, empirically used, can never prove anything else than disappointing.

To satisfactorily employ electricity, it is absolutely essential to possess some rational knowledge of the

force; and the apparatus must be as simple as possible in construction, and easy of repair—that is to say, perfectly under control.

The aim of these few pages is to show how electricity can be used to advantage in general practice, and the line of argument that has been adopted is as follows: Under the headings Constant current, Cautery, etc., as already mentioned, are described:

1. The special difficulties which the battery has in each case to contend against.

2. How they can be overcome.

3. How, by the help of a very simply constructed commutator, almost any kind of battery in ordinary use can be modified at a minute's notice to meet these requirements, and rendered applicable to every possible purpose for which electricity can be employed.

4. The construction of one form of battery is given in minute details. It can be easily made or easily repaired without the help of an expert.

A brief account is added of accumulators, with their advantages and disadvantages in medical and surgical work.

In the description of English-made secondary batteries, help must be acknowledged from Sir David Salomon's excellent little work on the subject.

Descriptions of experiments are only given where necessary to prove statements advanced, or to illustrate the context.

The plates are from photographs by the author, whose special thanks are due to his friend, Mr. T. Fardon, for his valued help and suggestions.

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ELECTRICITY IN GENERAL PRACTICE.

CONSTANT CURRENT.

For constant current.

When the constant current is used as a stimulant to diseased muscles, or as an anodyne and sedative for the relief of pain, the difficulty which the battery has to contend against is, to overcome the great resistance that the human body opposes to the passage of the current.

Battery must have high electro-motive force.

For this object (*a*) a great difference of potential must exist between the two terminals, *i.e.*, the battery must have a high electro-motive force.

Reduce resistance of skin.

(*b*) The resistance of the skin, which acts almost as an insulator, must be reduced to a minimum by the most perfect contact of the rheophores.

Unit of electro-motive force.

The unit of electro-motive force in practical use is termed a volt.

Battery.

To meet the first of the above requirements, one naturally selects cells of known high electro-motive force, such as:

Cells of known high electro-motive force.

A Grove consisting of a zinc plate, plunged in sulphuric acid, and a platinum in nitric. This gives 1·9 volts. A bichromate, composed of zinc and carbon plates, immersed in a solution of bichromate of potash (or chromic acid) and sulphuric acid. Gives 2 volts. A Leclanche, composed of a hollow carbon cylinder,

packed with peroxide of manganese, and immersed in a solution of ammonium chloride, into which a zinc plate is plunged. Gives 1·6 volts.

These three varieties are in common use. The objections to a Grove are :

(*a*) The very offensive nitrous fumes which are given off.

(*β*) The expense of platinum plates.

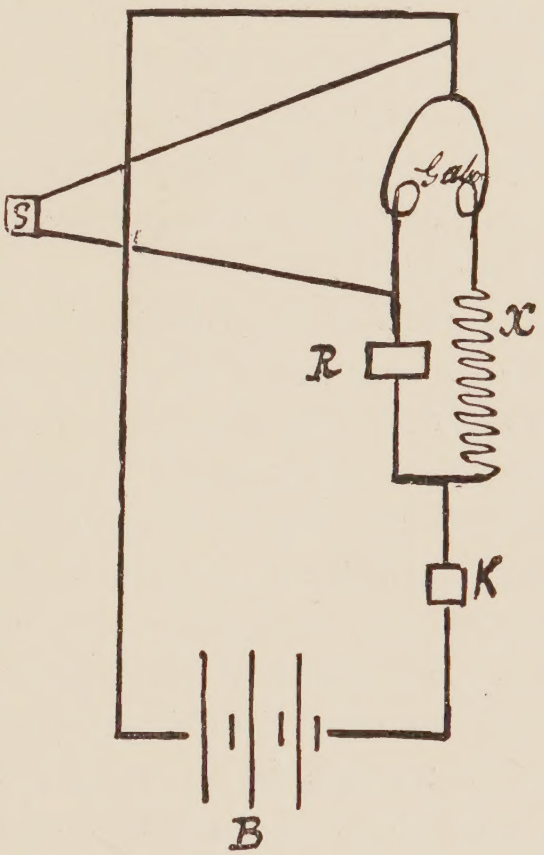
The *Leclanche* is extremely popular. There is very little waste when it is not in use, and it does not easily get out of order ; moreover, the cells are very inexpensive, but they suffer considerably from what is termed polarization. This is an expression one is constantly hearing. It means that as the current circulates through the cell it decomposes the electrolytes in the exciting fluid, and that here, as in all cases, in accordance with the law of conservation of force, work done cannot be lost—it must in some way be returned ; hence a counter electro-motive force is set up which opposes the current, and is just as detrimental as if the resistance of the cell had been rapidly increased. The offending product of the electrolytic decomposition is hydrogen, and it is not until it has been got rid of, as by its recombination with some compound in the fluid, that the cell can be said to have recovered itself. It is interesting to notice that in producing this condition of 'polarization' the hydrogen acts exactly as if another metal had been introduced into the fluid.

Polarization.

The application of the constant current to the body may be for two distinct purposes—(*a*) For diagnosis, and under this heading may be included the estimating of bodily resistance ; (*b*) as a curative agent.

The first subdivision is perhaps the most difficult portion of the whole subject, and presupposes a knowledge of electrical measurements; but it is absolutely necessary to introduce it here, as the phenomena exhibited in estimating bodily resistance illustrate and prove the best methods of application to adopt when using the constant current for the treatment of disease. Estimating resistance.

If an estimation is attempted of the resistance of any ordinary electrical cell, by one after another of the different methods to be found fully described in such textbooks as Latimer, Clark, or Jenkin, any practical electrician will admit that with every fresh arrangement adopted the chances are that some slight variation will be apparent in the result obtained.



The estimation of a cell resistance bears some comparison to the estimation of the resistance of the body, but the difficulties which pertain to the former are greatly increased when dealing with the latter: it therefore becomes a matter of great importance to select such a method that all sources of error may be, as far as possible, eliminated from the apparatus itself. For example: In any arrangement where a differential Selection of method.

galvanometer is employed, and the current shunted, a mistake may be easily made. Thus in the accompanying illustration, B is the battery, K the key, R the box of known resistance coils, and X the body resistance, to be estimated. The resistance of X being exceedingly high, it becomes necessary to shunt the current on the known resistance side. Now, if the current be allowed to flow for a very brief period, the wire in the shunt becomes heated sufficiently to markedly increase its resistance, perhaps by as much as from five to seven ohms. As in the final calculation this error is multiplied by ten, or perhaps a hundred, the total error may be very considerable.

Wheetstone bridge.

In the few experiments that follow, and in all cases in these pages in which a resistance is quoted, although other methods may have been employed, they have always been corroborated by a Wheetstone bridge arrangement, including a set of 1, 10, 100, and 1,000 ohm resistance on each side. The 100 ohm is put in on one side, and the 1,000 ohm on the other, when estimating bodily resistance. A box of known resistances (Siemens). A not too sensitive galvanometer. Two keys: one between the battery and the resistances, one between the resistances and the galvanometer. All the wire employed being of the same composition.

An estimation of bodily resistance.

A sheet of soft lead, sufficiently large for the whole foot to rest on, was placed in a bath of salt and water. On to this leaden plate was clamped one terminal from a battery consisting of two chromate cells joined in series. The other terminal was attached to a handle, which could be screwed into circular leaden discs of one, two, three, and four inches in area respectively. After well moistening the cervical region of the spine with salt

Effect of varying the surface area of the rheophore.

solution, and applying the one-inch disc, the key between the battery and the body was depressed. A few seconds were allowed for the current to become steadied, and then the second key was depressed, so that the current flowed also through the galvanometer. Resistance was 2,640 ohms. As discs of greater area were substituted, the resistance was found to proportionately diminish. With the four-inch disc, the resistance was rather under 2,000 ohms. With a sponge rheophore well moistened, and having an area of one inch, it was 2,730 ohms. With a band of thin lead made to encircle the neck, and well pressed on to the moistened skin, the resistance came down to 1,200 ohms. If these discs were allowed to dry, or the contact was not perfect, the resistance rapidly went up to 10,000 or 20,000 ohms. If the skin was very dry it was practically immeasurable.

Enormous increase of resistance as rheophore or skin dries.

The resistances here given are not due entirely to the resistance of the body. Allowance must be made for the opposing forces, polarization and self-induction. An explanation of polarization has already been given.

Polarization and self-induction.

Self-induction is no more peculiar to the body than is polarization. Any large conductor exhibits the same phenomenon, and must necessarily do so unless it were possible for it to be of exactly the same composition throughout. For the current breaks up and takes numerous different paths, the quantity passing through any one path being inversely proportional to its resistance, and an opposing current must be induced between all parallel adjacent paths. It is for this reason that a flat tape of metal is a better lightning-conductor than a circular rod, and a number of thin

Self-induction.

wires insulated from each, a better conductor than either.

Somewhat similar experiments to these here given were exhibited by Dr. Stone in his most excellent Lumleian lectures of 1886, in which he proved that bodily resistances had formerly been greatly over-estimated. He also attempted to allow for this self-induction by Mance's correction. His results were slightly lower than those here given. It is obvious that to obtain an estimate of bodily resistance which shall be of any scientific value is exceedingly difficult. Chemical compounds, acting as electrolytes, abound, and are constantly varying in amount and kind. Moreover, the current itself instantly modifies the conditions of the paths through which it flows. But it remains as an indisputable fact that an enormous economical advantage can be obtained by a proper application of the current. Resistance is seen to vary with the area which the rheophore covers, and with the degree of moisture of the skin.

Extreme difficulty of obtaining a reliable result.

If a thin, soft plate of lead is bound over the spine, the skin having been first thoroughly moistened, a wet sponge rheophore be used for electrical application to the muscles affected, and neither plate nor sponge be of diminutive size, the required conditions are fulfilled.

Great economical advantage obtained from good application of current.

In the experiments quoted, even four volts could be distinctly felt, and thirty volts would have been unbearable.

CAUTERY.

To heat the various instruments used for cautery purposes, the essential is *quantity of current.* To

Quantity required.

obtain this, the one thing necessary is to diminish the intra-batterial resistance. The unit of current is an ampere, which must be considered as a unit quantity passing through any point in a given wire per second. The quantity in amperes is equal to the electro-motive force of the battery in volts, divided by the resistance of the circuit (*i.e.*, the intra-batterial, plus the extra-batterial resistance) in ohms. The cells must be joined in multiple arc, or, as it is sometimes termed, in parallel—that is, all the carbons must be united together, and all the zincs together.

Unit.

Cells, how joined.

No matter how many cells there are, if they are joined in multiple arc, the electro-motive force remains constant. It would be exactly the same if there were fifteen cells as if there were only one. We often read that joining in parallel increases the quantity of current, by increasing the surface of the plates; but it is not advisable that this should suggest a conception similar in kind to that which would be derived from such a statement as: 'The larger the surface of boiling water, the greater the quantity of steam given off.' It is better to continually keep in mind that increase of surface increases the quantity of current, *because it diminishes the intra-batterial resistance.* This idea can never lead into error, for no matter by what means the constructor succeeds in diminishing the resistance of his cell, he will certainly by so doing increase the quantity of current given off. Moreover, the universal application of Ohm's law is more fully appreciated: that current equals electro-motive force divided by resistance.

Having shown what are the essentials for obtaining quantity of currents, a few illustrations will point out

Variations in grouping.

how modifications in the above method of grouping will lead to different results, which may be of particular advantage in special cases.

Let a battery be composed of fifteen chromate cells, each consisting of one zinc and two carbon plates, $8'' \times 4\frac{1}{2}''$ (for cautery).

If coupled up in three groups of five cells each, the cells of the group united in parallel, and the groups themselves united in series, the electro-motive force of the battery will be 6 volts. Suppose each cell to have a resistance of ·2 ohms, then each group of five will have a resistance of ·2 ohms divided by five = ·04 ohms. Now, since these three groups are united together in series, the three will multiply both the electro-motive force, which, as before stated, will be 6 volts, and the total resistance (disregarding for a moment that of the rest of the circuit) will be $\cdot 04 \times 3 = \cdot 12$ ohms. Therefore, the total current will be $\frac{6}{\cdot 12} = 50$ amperes. If these groups had been threes, the resistance of each group would have been $\frac{2}{3} = \cdot 0\dot{6}\dot{6}$, and the total resistance $\cdot 0\dot{6}\dot{6} \times 5 = \cdot 33$ ohms, giving a total quantity of $2 \times 5 = \frac{10 \text{ volts}}{\cdot 33 \text{ ohms}} = 33$ amperes nearly; obviously, if quantity alone is to be considered, not such an advantageous grouping as the first.

Resistance of instruments to be added.

But in estimating the total quantity of current, one has to take into account the resistance of the instruments. This should consist almost (for practical purposes one may say entirely) of the resistance of the part to be heated, as a platinum point. In Schech's instruments these average ·05 ohms; this has to be added to the battery resistance; thus, in Group I.,

total resistance = ·12 + ·05 = ·17, and total current = 35 amperes. In buying these instruments care should be taken to select a good holder. Often the contact of the small make and break key is extremely bad, as the following little experiment will show:

Result of resistance of instruments being too high.

Platinum wire, as used for Schech's instruments, and having a diameter of ·0295 of an inch, gave a resistance of ·034 ohms. This, when held in a holder similar to those usually sold, gave a total resistance for wire and holder of ·078 ohms, leaving ·044 ohms for the holder —far too high. The result was that the holder soon became hot in the hand, which it should not do, and it would probably soon be damaged. The high resistance of this holder was entirely due to the imperfect contact of the key.

Resistances of metals must be taken with cells giving small quantity of current.

In taking the resistances above mentioned, two cells only were used, so that the temperature of the instruments should not be sensibly raised, since the resistance of all metals increases with heat. (The contrary is the case with carbon and the human body, which decrease with heat.)

In forming some idea of the quantity of current that an instrument will require, the following facts are useful:

A platinum wire, diam. ·030 inches, length 11 cm., is raised to 77° by 10 amperes.

It becomes visibly red-hot with 20 amperes, and is fused by 30 amperes.

THE ELECTRO-MAGNET

consists of a bar of soft iron, brought to a point at one end, and surrounded by copper wire. The electric current traverses this wire, and lines of magnetic force

are induced in the bar in a direction at right angles to the current; the pointing of the bar focuses, as it were, the lines of force.

Unit an ampere turn.

The intensity of magnetization up to saturation-point *increases in direct proportion to the number of ampere turns* —that is to say, the number of turns of wire which surround the magnet multiplied by the quantity of current which that wire will carry. Curious to say, it makes no difference theoretically, and but very little practically, whether the wire is in direct contact with the magnet, or whether there is an interval between; as in the tangent galvanometer.

Increased length of wire compensates exactly for increased distance.

Consequently, this expression 'ampere turn' has become the accepted and established unit of electro-magnetic force.

If it were possible, we should obtain the greatest effect if the resistance of the electro-magnet nearly equalled the resistance of the battery; but our battery has to adapt itself to the instrument, and not the instrument to the battery. The chief consideration must be the sectional area of the wire surrounding the magnet.

If this wire be fine, and therefore with a high resistance, the arrangement of the cells must be such as to give a high electro-motive force; *i.e.*, in series. It has been shown under the heading 'Cautery,' by examples of different groupings, that this arrangement of cells will necessarily be accompanied by a high intra-batterial resistance.

If, on the contrary, the magnet be surrounded by thick wire, with a low resistance, the arrangement of

cells must be such that the proportional quantity given off shall be greater, and the proportional electro-motive force shall be less; *i.e.*, in multiple arc. By this arrangement the intra-batterial resistance will be lowered.

The resistance of wire varies inversely as its sectional area.

Thus in any case the resistance of the battery can be made by modifications in grouping to approach the resistance of the electro-magnet, and the greatest effect will be obtained.

ELECTROLYSIS.

In Dr. Poore's work on 'Electricity in Medicine and Surgery,' the following statement will be found:

Dr. Althaus says: 'In 1866 and 1867 I made a series of microscopical observations on the changes which animal structures undergo under the influence of the electrolytic action of the galvanic current. The general result of these investigations has been that no animal tissue whatever can withstand the disintegrating effect of the negative pole; *and that the force and rapidity with which this disintegration is brought about are directly proportional to the electro-motive force which is employed, and the softness and vascularity of the structures acted upon.*'

This statement is misleading, to say the least of it, for electrolysis is entirely dependent on quantity of current, and the only object of the high electro-motive force is to get a larger quantity of current through a tissue of great resistance. A number of instruments in use illustrate this, as the electrical meter of Edison, and the ordinary voltameter, which is really an ammeter, and registers quantity. It takes its name from its inventor.

Amount of electrolysis directly proportional to the quantity of current.

By means of this apparatus sulphate of copper undergoes electrolysis; the amount of copper deposited is weighed, and from it can be estimated exactly in amperes the quantity of current which the battery employed is giving off. Suppose three cells giving six volts to be decomposing water. Double the number of cells (and by so doing the number of volts), and it is granted that the amount of decomposition in a given time will increase; but the quantity of current has increased also. Now double the surface area of the plates (but not the number of cells), and the amount of decomposition will be found to increase in direct proportion. The quantity of current has increased, but the electromotive force has remained constant. Consequently, given two batteries with an equal electro-motive force, the one having the lower intra-batterial resistance will have the greater electrolytic power. A high electromotive force is often required on account of the enormous resistance of the tissues.

As to the softness and vascularity, the more fluid there is in a tissue, the lower its resistance. Dr. W. H. Stone in his Lumleian lectures showed the enormous diminution of resistance which takes place on the occurrence of dropsical effusion.

INDUCTION COIL

illustrates the conversion of quantity of current into electro-motive force.

Thick wire connected with the battery surrounds a central iron core, and forms the so-called 'primary circuit.' Thin wire (and therefore with high resistance) connected with the rheophores surrounds this primary circuit, and forms the 'secondary circuit.'

As the current passes through the primary coil it converts the iron core into an electro-magnet.

A small vibrating hammer rapidly makes and breaks the current in the primary circuit. At each make a current is induced in the secondary coil; at each break a second current is induced, but opposite in direction.

Ampere turn.

Here again, as in the electro-magnet, *the number of turns of wire* is the point to be specially considered. In the primary coil the turns are few, and the resistance of the wire low; consequently, the electrical energy is exhibited in the form of quantity of current. In the secondary coil fine wire is used, in order to get a large number of turns round the magnet; and the exhibition is in the form of high electro-motive force. The intensity, then, of this secondary current depends on the number of turns, the degree of magnetization of the central core, and the rapidity with which the primary circuit is made and broken.

Perhaps the best induction apparatus is Gaiffe's sulphate of mercury. In one tested, the resistance of the primary coil was ·7 ohm; of the secondary, 103 ohms; the flexible wire, 1 ohm. The two small cells gave a combined electro-motive force of three volts.

LIGHTING.

The common form of incandescent lamps—*i.e.*, those in general use—are composed simply of a fine filament of carbon, bent in the form of an arc, and placed in a glass globe from which air has been, by means of a Springel air-pump, as far as possible excluded. The luminosity depends on the fact that a carbon filament, when placed in a circuit with sufficient current, be-

comes luminous, and does not disintegrate when in vacuo.

A 'Watt,' the unit of total electrical energy.

A catalogue of electric lamps generally gives the number of 'Watts' which they require. The Watt is the unit of total electrical energy, being current in amperes multiplied by electro-motive force in volts.

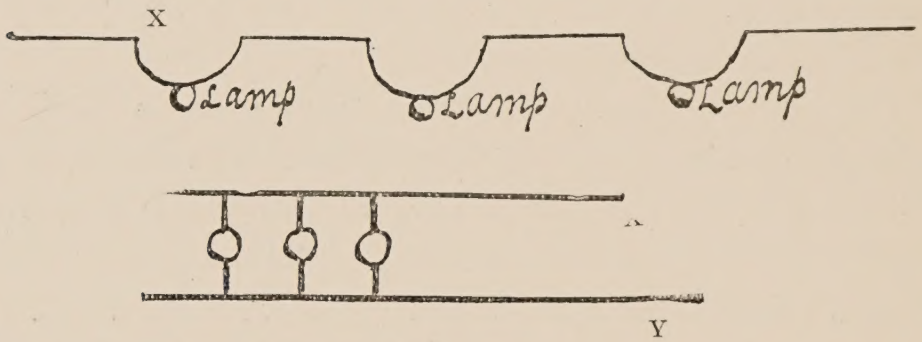
It has already been shown that the cross-sectional area of a wire of given length determines both the electro-motive force and the current; consequently, if

Number of volts to be considered.

the electro-motive force required is known in volts, the quantity need not be considered. If we get the volts right, the current must be right also.

This holds good no matter how many lamps may be in use at the same time, or how arranged, whether in series or in multiple arc, thus (the ends X and Y are not joined).

Arrangement of lamps—in series, and multiple arc.



In arrangement 1 the current is constant, and the number of volts varies with the number of lamps. If each lamp requires 50 volts, then three lamps in series would require 150 volts, the quantity remaining the same.

In arrangement 2 it is the quantity that varies with each lamp, for the more lamps one puts in the greater the combined sectional area of wire through which the current passes, and hence the lower the resistance the greater the quantity of current.

So that in both instances the rule holds good. If the number of volts be known, the amperes may be disregarded. Practically it is far easier to deal with volts than amperes.

It would be beyond the limits of these few pages to enter further into this branch of the subject. *Primâ facie*, it may appear that the question of lighting is of little interest to the medical man. His requirements in this direction are few; he rarely, *if ever*, uses more than one lamp at a time for professional purposes, and the volts that this is likely to require are easily furnished by any ordinary primary or secondary battery. To the electrical engineer, however, the question is all-important on account of the extensive field for its application. The result of so many workers and so much thought is that improvement follows improvement with such extreme rapidity that electric lighting is almost an unwritten science.

Electricity is a most plastic form of energy, and if it is to acquire a more extended application in surgery and medicine, one may safely prophesy that this plastic attribute will be a special reason why.

Nothing conveys a better conception of the correlation of all force than the study of electricity, and nothing illustrates the conversion of electrical force so well *or suggests so much* as the machinery used in electric lighting.

BATTERY.

THE construction of this battery is given in minute detail, so that it can, with the help of an ordinary carpenter, be easily constructed.

It will be found of considerable advantage, where room permits, for the battery to be of rather large size. Quantity of current is more easily obtained, and the cells need not be so frequently replenished.

The number of cells employed in this description are fifteen; more can easily be put in if desired, but if the method of application previously mentioned be adopted, it will be found difficult to find cases that require, or patients that can bear, more than thirty volts.

The frame-work will best be understood from the diagram.

Description of frame.

The top-piece (A) is 4 ft. $3\frac{1}{2}$ in. long, by 1 ft. 5 in. broad, by $\frac{3}{4}$ in. thick.

The wooden pillars (B) which support it are 26 in. high, 2 in. broad, $1\frac{1}{2}$ in. thick.

C is the frame for supporting the plates. It is $48\frac{1}{2}$ in. long and $12\frac{3}{4}$ in. broad, and is divided by a strip of wood running down the middle into two halves, simply because the cells are in two rows.

A separate compartment, $5\frac{1}{4}$ in. square, must be put in at one end, for the 15th cell. There is a groove at either end to receive pillar G, for the purpose of steadying the frame.

The vulcanite projecting from either side of the plate lodges on the frame, which may be grooved to receive it, but the weight of the plates keeps them in position.

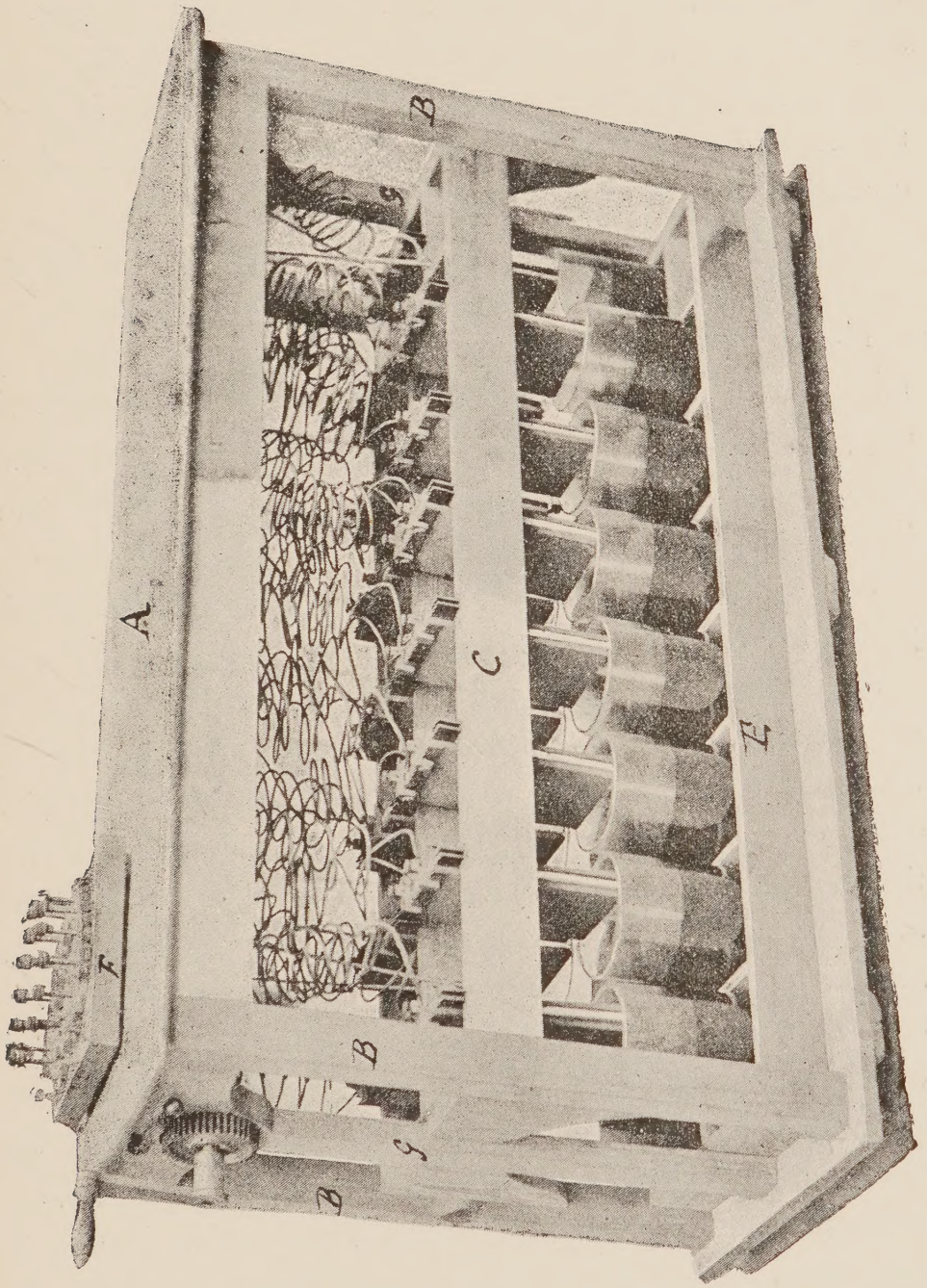
The frame is raised and lowered by cords, which are wound and unwound on an iron bar, running just under the top board from end to end.

D is the handle for turning the rod, furnished with a cog-wheel and catch. It fixes the plates at any required height.

E, the floor for the glass jars, is divided into shallow compartments, $5\frac{1}{4}$ in. square, to keep the jars in place. Its dimensions correspond to those of the top board.

The whole structure moves easily on castors.

Plates, zinc, 8 in. long, $4\frac{1}{2}$ in. broad, by $\frac{1}{4}$ in. thick.


B
A
C
T
B
T
B
B

Cells. They must be well amalgamated by rubbing them over, first with a little sulphuric acid and then with mercury. A thin layer of metallic mercury is deposited on the surface on the zinc. A little clamp must be *screwed* into the top of each zinc.

Carbons, two to each zinc, so that both surfaces of the zinc are in action at the same time. The size must correspond to that of the zinc.

Vulcanite should be used for separating these plates from each other.

It should be about 3 mm. thick, and cut $6\frac{1}{2}$ in. long, by 1 in. broad. Vulcanite is infinitely better for separating the plates than wood. It is very light, a perfect insulator, and allows the plates to be brought very near together, which is all-important.

Not quite an inch projects from either side of the plates for resting on the frame.

A plate of brass of a length equal to the breadth of the carbon, $\frac{1}{2}$ in. broad and 2 mm. thick, should be placed along the upper part of the outer surface of each carbon; it greatly improves the contact. The three plates must be safely secured by *two clamps*, bridging across them; the clamp must have a span of at least $1\frac{1}{8}$ inches. The wire employed should be copper, coated with cotton braid; number 16 imperial wire gauge answers well. A wire must be attached to each zinc clamp, and a wire to one of each pair of carbon clamps. Each wire must be curled spirally, to allow the raising and lowering of the plates. It must then be brought along the under surface of the top-piece A, and kept in position by little U staples, as used by bell-hangers. Finally, it should be brought through

Arrangement of wires.

holes at the handle end of the top board, to be attached to the commutator F.

In the description of the commutator it will be shown how by its means this battery can be made to answer every purpose required.

The battery should be furnished with a cover made of American cloth, or some such material, to prevent dust and the like from getting in; but space must be left for the commutator to project through. It may then occupy the position, and answer the purposes of an ordinary table.

It may save some trouble if mention be made of firms where the various articles here enumerated can be obtained. Warehouses dealing in electrical goods regulate their stores according to the requirements of electric lighting and dynamic electricity. The primary battery is no longer worthy of their consideration. For this reason it is often difficult to obtain everything required from the same place.

Purchase of apparatus.

Carbons are of two kinds: moulded and cut. The cut are the more expensive, but are said to withstand acids better; very good ones can be bought of Lynch and Co., Aldersgate Street, of the size here mentioned, at 1s. 3d. each. *Moulded* are considerably cheaper, and I think answer the purpose equally well. The Globe Electrical Company, 7, Carteret Street, Westminster, exhibited moulded carbons at the Health Exhibition, which they guaranteed to withstand the strongest acid solutions. I have had some from them in use for three years, with a result in every way satisfactory. The price depends to a great extent on whether a stock size can be used, or whether they have to be moulded to

order. This is one of the most likely firms that could be named for obtaining all that is required.

If not, zincs and clamps can be bought at Stanton's, Bride Street, Farringdon Street. The price varies with the market price of zinc.

Wire can be obtained at Ormston's, Old Street, Goswell Road, London.

Glass jars can be bought at any good glass-blower's, as Cette, Edward Green and Co., Lambeth. The size required depends, of course, on the size of the plates; for this battery they must be 8 in. high by $5\frac{1}{2}$ in. in diameter.

The exciting fluid for the chromate battery consists of a mixture of chromic acid (or bichromate of potash), sulphuric acid, and water.

Electro-motive force of the plates in water alone.

Zinc and carbon plates plunged into plain water give an electro-motive force of 1·5 volts nearly; but the intra-batterial resistance of such a cell would be exceedingly high; consequently, the quantity of current given off would be small. Moreover, the cell would suffer greatly from polarization, which would at once become apparent by the cell appearing to rapidly 'run down.' When sulphuric acid is added to the water, the intra-batterial resistance is considerably diminished, and the quantity of current proportionally increased; but again the effects of polarization become apparent almost at once, and the cell soon runs down.

The use of the sulphuric acid.

The use of the chromic acid.

Chromic acid is an anhydrous acid formula, C_rO_3, and when added to the sulphuric acid solution it takes up the offending product of intra-batterial electrolysis, namely, hydrogen; and so long as chromic acid remains uncombined, the cell will not suffer from polarization. If bichromate of potash be used, it is

split up by the sulphuric acid, the chromic acid alone being of service.

The proportions.

On reference to various text-books, it will be found that widely different proportions are given for the chromic acid, or bichromate. From the above it will be readily understood that, within reasonable limits, the quantity used at any one time makes but little difference. If double the quantity is used it will last, with a constant amount of work, double the time. Chromic acid appears to the writer, after considerable experience with both, to be far superior to the bichromate. The electro-motive force of the chromate cell is 2 volts, against 1·9 volts for the bichromate; and the former is far more constant than the latter. Comparing the amount of work which each will do, the use of chromic acid is no more expensive than that of the bichromate; and as it is readily soluble in water, and the bichromate dissolves with some difficulty, it allows of a great saving of labour. An objection sometimes raised against chromic acid is that it clogs the plates, which the bichromate is said not to do. I have never experienced this. Good chromic acid is so soluble that it is difficult to imagine how it can occur. One ounce of water will readily dissolve one ounce of the acid.

The following proportions are as satisfactory as any:

Water, 2 pints.

Chromic acid, 5 oz.

Sulphuric acid, 3 oz.; the common oil of vitriol answers every purpose.

The mixing of the fluid.

Measure the jars by lowering the plates, so that displacement may be allowed for; and allow also for the addition of the sulphuric acid. Add the requisite

amount of chromic acid, which will become almost instantly dissolved in the water; then slowly add the sulphuric acid. The fluid should be left for twelve hours before using.

Mark the glass jars, in order to remember the fluid-level; and once a fortnight add water, to compensate for the loss that has taken place by evaporation. The strength of the exciting fluid is in no way diminished by this addition.

How to judge of the condition of the fluid and of the plates.

A good indicator of the condition of the fluid is the way it acts upon the platinum wire of the galvano-cautery. When the fluid is perfectly black, and produces no longer even a temporary glow, it may be considered to be completely exhausted.

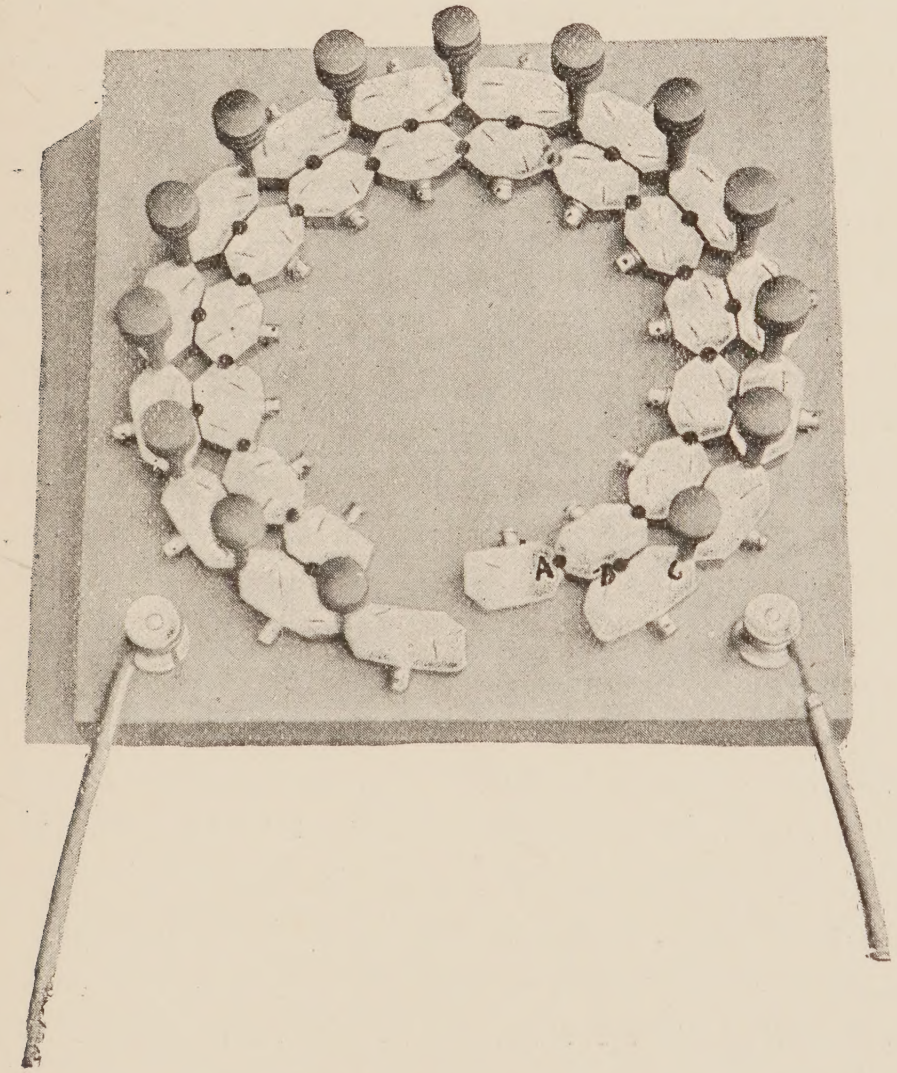
If the platinum glows for a moment or so immediately on making contact, the glow then slowly dying out, the battery is suffering from polarization, and the fluid requires more chromic acid.

If the plates hiss on being immersed, the zincs are not properly amalgamated.

COMMUTATOR.

THE idea for this commutator is taken from the arrangement employed in an ordinary box of resistance coils.

It may be bought for twenty cells, and can be used for twenty or any number less than that; but as the



battery first described had fifteen cells, it will be simpler to describe a commutator for the same number. Description.

Brass blocks, thirty in number, $1\frac{1}{4}$ in. long, $\frac{3}{4}$ in. broad, $\frac{1}{4}$ in. thick, are arranged in two rows of fifteen each, in the form of a not quite complete circle.

The blocks are all numbered, each number corresponding to a cell.

A screw is inserted into the inner aspect of each block in the inner row, and the outer aspect of the outer row, for the attachment of the wire.

The outer row is attached to the carbon plates, the inner to the zinc.

It will be noticed that the first zinc commences one further back than the first carbon, and the last zinc terminates one further back than the last carbon. A space of about $\frac{1}{20}$ in. separates these blocks from each other.

A hole for the insertion of a brass peg is situated between each block and the next to it, and also between each block and the block by its side.

When all the blocks are united by pegs the sectional area is so great that practically no resistance is offered to the passage of the current.

The fifteenth zinc is united to the right-hand, the first carbon to the left-hand corner binding screw.

The three rows of holes are named for descriptive purposes A, B, and C, from within outwards.

For the Constant Current.—Supposing pegs to unite all the blocks in the outer row from 1 to 15, then, if the plates be lowered into the exciting fluid, one cell is in circuit—namely, cell 15; for 15 zinc is directly connected with the terminal binding screw, and 15 carbon is connected with 1 terminal through the outer row of blocks.

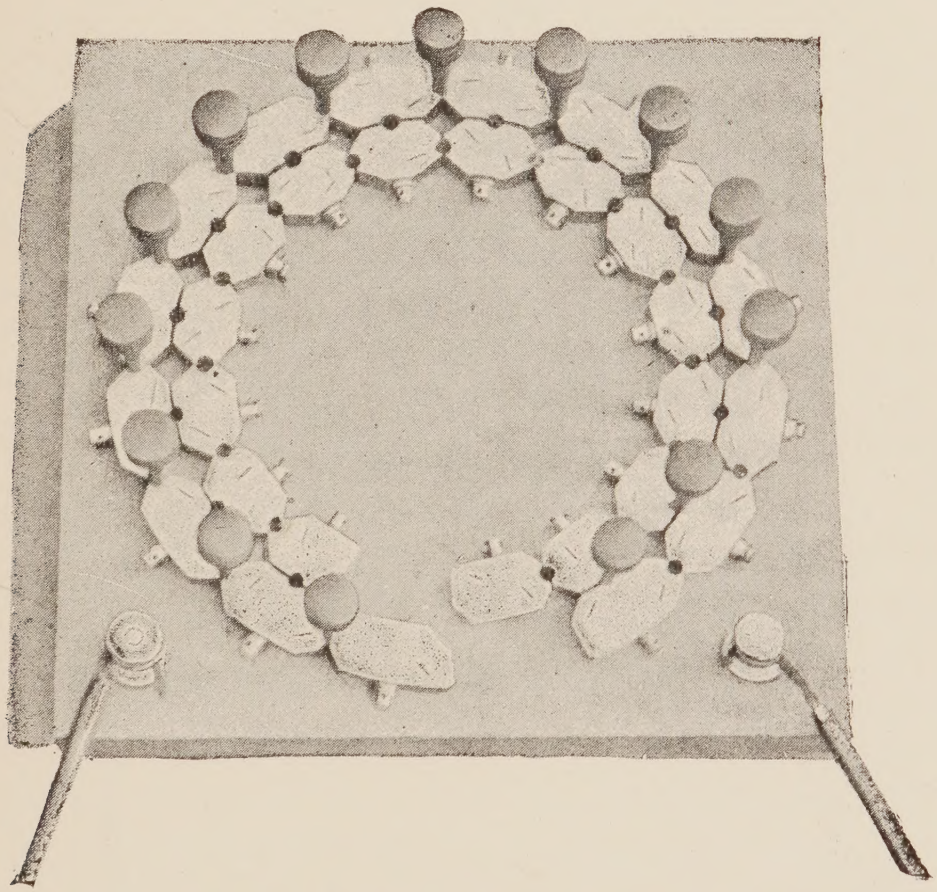
To increase number of cells joined in series.

To instantly add any number of cells in series is merely a matter of moving the pegs *already on the board.*

EXAMPLE. To put in two more cells, move the two

end pegs in row C to the two end holes in row B, as in the illustration, then three cells are united in series; for zinc 14 is united to carbon 15, zinc 13 to carbon 14, carbon 13 to zinc 13 through the battery, and to the terminal, as before, through the outer row of blocks.

This arrangement is very useful, not only because it allows of a rapid increase of the number of cells one



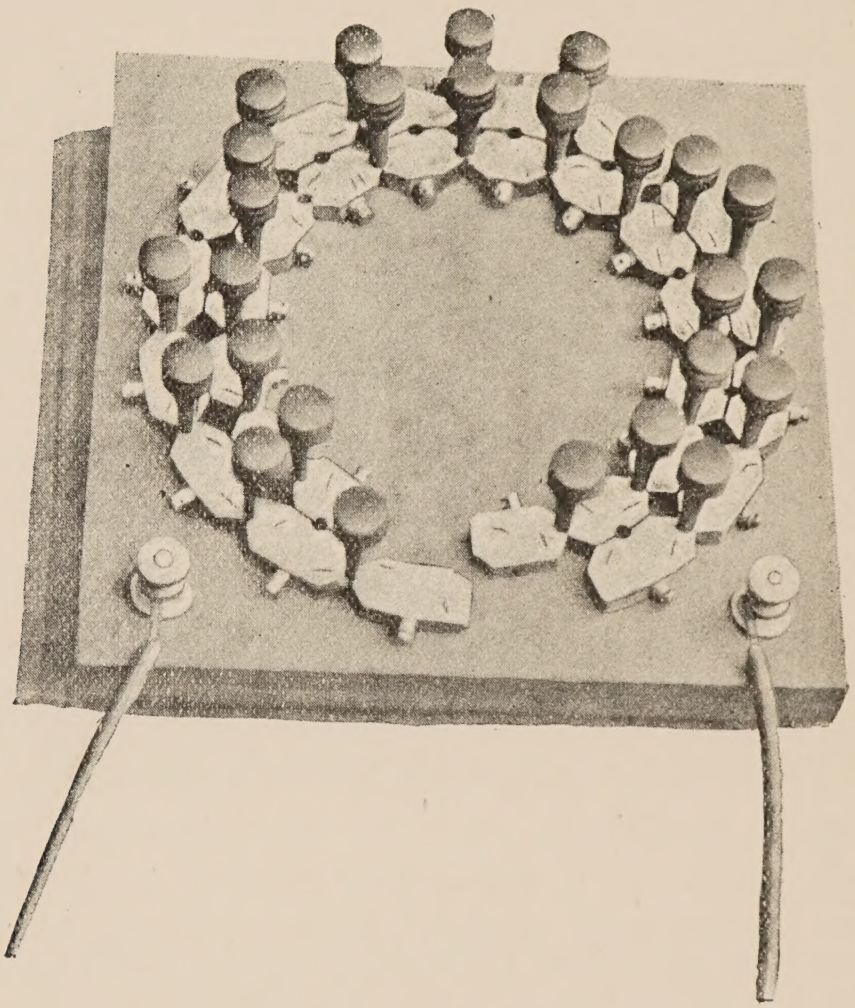
at a time, for many other commutators will do the same, but also because if any one cell happens to get out of order, it can instantly be shut out without in any way interfering with the rest, until such time as it can be repaired.

To shut out any cell required.

EXAMPLE. Suppose that pegs fill all the holes in row B, joining al the cells in series, and it is required to shut out cell 10. Move the peg joining 10 and 11 to

the hole between 10 and 11 row C, and cell 10 is shut out; for the carbon of 11 is joined to the zinc of 9 through the block 10. Any number of cells could be shut out if required in a similar way.

Or if it be required to take in any one cell alone (as



for experimentally testing the battery), this can easily be done.

To use any one cell.

EXAMPLE. Let it be required to put in cell 10 alone. Then pegs would be placed in row A from 15 to between 11 and 10 inclusive, and in row C from 1 to between 9 and 10 inclusive.

Cautery.—It is advisable to arrange the cells in three groups of five each, the cells in the group being joined in multiple arc, the groups united together in series. Best arrangement of cells.

The first time of using an instrument gradually lower the plates until the cautery is at the required heat. The operator soon learns the position of the handle of the battery for various instruments, and it can at once be put at this.

For the above grouping commence between 1 and 2 in rows A and C, and put in four pegs in each row, then miss a hole, then four more pegs, and so on right round. To join these groups together in series put in a peg in row B between 5 and 6, and 10 and 11. How accomplished.

The desired arrangement is then completed. In a similar way any combination can be made.

Although it takes some little time to describe these groupings, it takes but a few seconds to do them.

For Lighting.—When the lamp is bought it should be ascertained if possible what it requires in volts. Almost all the incandescent lamps take about an ampere of current.

The first time of using any lamp, put in cells joined in series to produce 2 volts less than the lamp is expected to take, then gradually lower the plates. If the lamp does not glow well, put in another cell. The principal danger is from commencing with too high an electro-motive force. If any minute particles of carbon are seen on the glass after illumination, the glow of the lamp has been too great. If no particulars can be obtained of the number of volts required, the number of cells joined in series must be increased one at a time until a good glow is obtained. Principal danger.

After the first time the requirements of the lamp are known and can at once be employed.

Endocystoscope.

The lamps used in the endocystoscope have a resistance varying from 9 to 12 ohms. They take a fraction more than an ampere of current, and therefore require from 8 to 10 volts as a rule.

If plates are large, add one at a time in series; if small, add two at a time in series—the pairs being joined in parallel.

Electro-Magnet.—Practically the electro-magnet presents but very little difficulty for the battery. Those generally sold are surrounded with wire of medium resistance, as about 2 ohms. All that is necessary with large plates, like those in the battery here described, is to put in one cell at a time, and keep adding them in series until it is found that no further increase in the magnetic force takes place. If the plates are smaller, group them two at a time, and add as before. It is next to impossible to do the instrument any harm.

One cell of battery is sufficient.

Induction Coil.—One cell of any ordinary battery is generally sufficient to work the induction coils in common use. The terminals from the battery are easily clamped on to the primary coil, and the one pair of plates can be lifted off the supporting frame and placed in the exciting fluid. If more cells appear necessary on account of the small size of the plates, they must be joined in multiple arc.

The rapid make and break of the primary circuit does not allow time for any cell or cells to completely saturate the electro-magnet.

Electrolysis.—In using electrolysis for any surgical purpose whatsoever, our only real guides are physical signs and physiological effects.

We know that all electrolytic decomposition is in direct proportion to the quantity of current, and since the resistance of the body is exceedingly high, it re-

quires a high electro-motive force to get a sufficient quantity of current through.

In many descriptions of operations in which electrolysis was employed, we read that a galvanometer was introduced into the circuit, in which galvanometer a given deflection indicated a definite quantity of current. Unfortunately, however, in the case of the body, even if we know the quantity of current used, it conveys no definite conception to our mind of the work done. The knowledge is interesting, but not necessary for the performing of the operation.

A galvanometer not absolutely necessary.

In all cases, therefore, where electrolysis is to be employed, it is a matter of adding cells joined in series until the desired result is obtained.

This commutator can be obtained of Messrs. Maw, Son, and Thomson.

ELECTRICITY RENDERED PORTABLE.

THIS can be accomplished in three distinct ways: As dynamic electricity, as stored electricity, and as electricity generated from a portable primary battery.

The first of these methods must unfortunately be very briefly disposed of. It may possibly interest some to learn that, as the result of experiments made in this direction, it is possible to make a most completely portable apparatus, with a cell as a motor and a small dynamo as a multiplier, so to speak, of electrical force, and to exhibit this force in the form of quantity or at a high pressure. But the introduction of an instrument of this kind would justly be met with the criticism that even if the number of sections in the armature be considerable, the dynamic current cannot be represented by a perfectly straight line. It always exhibits a slight fluctuation: and that such a current is more likely to be injurious to nerve tissue than the more perfectly constant current of the primary or secondary battery. No help can be obtained, as far as the author is aware, as to the extent to which this is the case, or as to the effect of dynamic electricity on the human body in health and disease.

Dynamic electricity.

ACCUMULATORS.

IN accordance with the law of conservation of force, chemical compounds, decomposed by the electric current, can, on recombining, exhibit work expended in their electrolysis again in the form of electricity.

Definition.

An apparatus, capable of receiving electrical energy, storing it in the form of work done, and returning it as

the electric current, is known as an accumulator of that force.

Of the varieties which have been introduced in England, two types have alone come into general use.

The oldest of these, the Planté, consists briefly of cells, usually composed of glass, containing sheets of malleable lead plunged in dilute sulphuric acid.

Planté accumulator.

From what is to be the upper edge of the plate, a piece of lead, known as a 'lugg,' projects, so that the plate can be entirely immersed in the acid solution. The plates are insulated from each other, but the luggs of all the alternate plates are connected together. Two groups are thus formed in each cell. These are attached respectively to the positive and negative terminals of the dynamo or any charging battery. The number of negative exceeds the positive by one, hence in every cell the ends are occupied by negative plates. Before compiling, the plates are often immersed in nitric acid to render them porous, and so increase the surface exposed to the electrolyte (dilute sulphuric acid). After 'grouping,' the cells are, by frequently charging and discharging them, what is technically termed 'formed.' This also is with the object of increasing the surface. The second variety is the popular English accumulator. made and sold by the Electric Power Storage Company, It consists of plates, or technically 'grids,' of lead, perforated as thickly as possible with square holes. These holes are filled with a paste, composed in the case of the negative plates of sulphuric acid and lead monoxide; in the positive of sulphuric acid and minium (formula, PbO_2 2PbO), a dull, reddish-looking compound.

Pasted plate accumulators.

The positive and negative plates alternate, and are insulated from each other by rubber rings placed verti-

cally. They are immersed in dilute sulphuric acid, and are connected by luggs, much in the same way as in the Planté accumulator.

Changes which the chemical compounds undergo during the charging of the accumulator.

An account of the changes which several chemical compounds in solution undergo during the passage of the electric current must always be to some extent speculative. In the case of this accumulator, it is certainly a sulphating, an oxidizing, and a deoxidizing process, and is probably somewhat as follows: The positive plate, as already mentioned, is composed of

$H_2SO_4 + PbO_2$ $2PbO$ in the paste.

$H_2SO_4 + H_2O$ in the fluid electrolyte.

The SO_4 in the paste goes to the fluid in exchange for the O of the water.

The H_2 combines with the SO_4 to form sulphuric acid; the O passes to the paste, converting the minium into a higher oxide. This view is corroborated by the facts that the plate is seen to turn of a puce colour—the colour of the higher oxide, and the sulphuric acid solution is found to increase in specific gravity. But not all the liberated H combines with SO_4; some of it passes to the negative plate, combines with the oxygen, and reduces the lead monoxide to metallic lead. The sulphuric acid of the fluid is not supposed to take any material part in these changes; it has the effect of lowering the resistance of the cell. Discharging is a complete reversal of this process of charging.

Electro-motive force accumulators.

The electro-motive force of these accumulators is 2 volts. No known accumulator gives more.

The electro-motive force of the battery used for charging must rather exceed that of the accumulator. For every 2 volts (accumulator) the battery must give 2·4, and this at the terminals; for it must be re-

membered that the electro-motive force at the terminals is influenced largely by the resistance of the external circuit. If the terminals were joined by a thick wire offering practically no resistance, then the number of volts there would be nil. In order that the volts at the terminals shall correspond to the theoretical number, one may imagine an ideal circuit, with the resistance of the extra-batterial portion infinitely high, and that of the intra-batterial portion infinitely low. The resistance of the human body is so great in comparison to that of the battery, that the maximum electro-motive force may be considered to exist at the terminals. The resistance of accumulators is very low, on account of their extensive sectional area; but immediately the current is passed into them a counter electro-motive force is set up, which acts practically the same as a resistance. Commercially, accumulators are always charged by the help of a voltameter; where no such instrument is to hand the desired result will be easily attained if, as stated above, 2·4 volts be allowed for each accumulator; *i.e.*, six chromate cells for five accumulator cells. The resistance of small accumulators is proportionately higher than in those of larger size, and they are not so easily damaged. The larger the plates in the primary (charging) battery the better. If not, the battery resistance will be high, and it will expend an excess of energy upon itself.

Charging battery to give 2·4 volts for each accumulator.

The current should be allowed to flow until bubbles of gas rise freely to the surface. The accumulator should never be discharged too rapidly, and never be allowed to completely discharge itself; in either case the lead monoxide flakes off.

It has already been mentioned that one effect of

sulphuric acid is to lower the resistance of the battery. But it appears to have another action; for as the accumulator continues to discharge, the specific gravity of sulphuric acid solution diminishes. Where electricity is extensively stored, this fact is taken advantage of to indicate the degree to which the accumulator is charged, and the rate at which it is discharging. Thus, taking the specific gravity of water as 1,000, sulphuric acid is added until the specific gravity = 1,200. As the discharging goes on, a hydrometer indicates the lowering of the specific gravity until (if the accumulator be completely discharged, which, as before mentioned, it should never be allowed to do) it reaches 1,100.

Specific gravity of H_2SO_4 solution the indicator of the store of electricity in the accumulator.

An accumulator can be charged from any generator of the electric current—primary battery, dynamo, or, as was suggested by Dr. Ogston, of Dublin, in an interesting article he inserted in the *Lancet* of April 30, 1887, by a thermopile. Dr. Ogston was using at the time the old Planté accumulator.

Advantages and Disadvantages.

Among the defects which are generally acknowledged to pertain to accumulators, the following appear specially worth noticing here:

1. They are easily damaged if rapidly discharged. Surgical cautery instruments require a rapid discharge.

2. Charging increases the volume of paste in the position plate, which, being immersed in liquid, and consequently but little supported, disintegrates, falls out, and short-circuits the current. The more the accumulator is moved about, the greater is the danger of this occurring.

3. The plates often bend at different parts, the surface becomes distorted, and the current is short-circuited from what is technically termed 'buckling.'

4. If allowed to completely run down, accumulators soon spoil. This is principally due to the formation of higher sulphates of great resistance, which cover the surface with a kind of enamel, and render the part so covered practically useless.

Many of these disadvantages are got over by an accumulator recently invented by Dr. Schoop, of Zurich, and being made at the Oerlikon works in Switzerland. A most favourable notice of it appeared in the *Industries Journal* of June 7, 1889. The special feature of these batteries is that the electrolyte is solid. It is of a gelatine-like appearance, and said to be entirely organic. The support given to the plates by a solid instead of a liquid prevents short-circuiting from any such cause as disintegration of paste or buckling. The current is not arrested, even if the vessel happens to crack.

The charging can easily be accomplished by any generator of the current, it being merely necessary to float a little water on the surface before commencing.

These accumulators permit of a rapid discharge without any damage to the plates, and their capacity is weight for weight equal to that of any English-made battery.

Since durability, portability, and rapid discharge are all great advantages in secondary batteries intended for surgical work, these accumulators seem almost as if specially designed. To some who frequently require to use the galvano-cautery at patients' houses, and where the charging can be easily accomplished from a

general house supply, or from a large battery of low resistance similar to the one previously described, these accumulators might be of great service.

But it must be remembered that no known accumulator gives more than two volts, and since lead enters largely into their composition, weight renders them practically useless for the constant current or electrolysis. No one would care to carry about a sufficient number of them to give a serviceable number of volts.

The use of any accumulator is, therefore, limited to heating a galvano-cautery, lighting a small lamp, the electro-magnet, and the induction coil. Where electricity is required for every purpose to which it can be applied, it is difficult to understand how any accumulator can be as serviceable as a simply constructed primary battery.

DESCRIPTION OF A PORTABLE PRIMARY BATTERY.

THIS battery measures 17½ in. long, 9½ in. broad, and 10 in. high.

It contains 12 glass cells (A). Square on section, and holding, if completely filled, 16 fluid ounces. Contents of case.

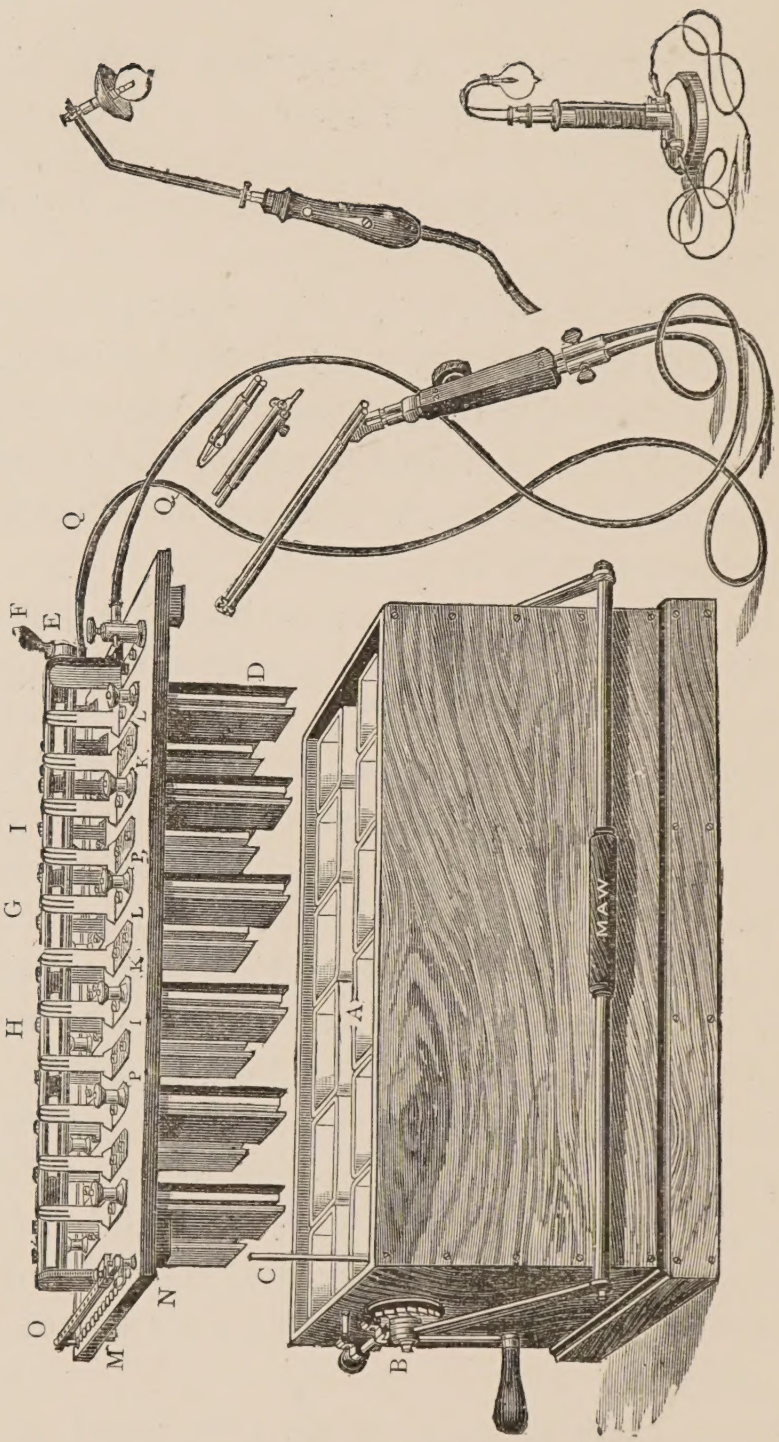
These jars stand in two rows of six each on a movable frame, which can be raised, lowered, and arrested in any position by the handle and cog-wheel with catch arrangement seen at B.

C is a brass rod, which passes through a hole in the lid. It answers the double purpose of guiding the frame, and showing to what depth the plates are immersed. The top-piece of the battery can be lifted on and off. It is composed of vulcanite. To the under surface the plates are attached in twelve groups, each group consisting of two carbons and a zinc (D). Lid, under surface

On the upper surface of the lid are arrangements by which the cells can be coupled in series or multiple arc, and if in series, can be added one at a time. Lid, upper surface.

The centre, for nearly the whole length, is seen to be occupied by E, a vulcanite rod 16 in. in length, 3 in. in circumference, and raised about an inch by supports placed at each end. It is furnished with a handle (F), by which it can be rotated through an arc of rather more than 90°.

G and G are strips of brass ¾ in. broad, attached diametrically opposite each other along the whole length of E.


A
B
C
D
E
F
G
H
I
K
L
M
N
O
P
Q
MAW

H and H (not well shown in the illustration) are the heads of screws, placed at regular intervals along G and G. They do not touch the metal on their own side, but are firmly driven into G and G on the opposite side.

I and I are also strips of brass $1\frac{3}{4}$ in. long, attached at equal distances along the circumference of E between G and G.

K and L are bright and black pieces of metal bent at right angles. The horizontal portions are attached respectively to the zincs and carbons beneath them.

The vertical portions are unattached, and press against E. From each of the zincs a wire is brought (embedded in the vulcanite) to one of the row of metal discs marked M, by which arrangement the cells, when joined in series, can be added one at a time by moving the small contact N along the rail O.

P P are screw clamps by which the zincs can be removed when worn out, or requiring to be reamalgamated.

Q Q are the terminals.

Cells joined in series.

When the rod E is in the position shown in the diagram, the cells are coupled in series, for the carbons are joined to the zincs in the group next to them by I.

Cells joined in multiple arc.

If E be rotated, all the metals connected with the carbons of one side rest on G, and all those of the other side rest on the heads of the screws, through which they also communicate with G. In a similar manner all the zincs communicate with G, and the cells are coupled in multiple arc.

The instruments figured are for cautery and lighting. The holder offers practically no resistance, the contacts are so good. The make and break is accomplished by

a screw; turned by the finger as easily as the wheel of an ophthalmoscope. The screwing movement keeps the surface clean and free from dust (which is of high resistance). The cells must be half filled with a sulphuric and chromic acid solution similar to that already described. Their combined electro-motive force is 24 volts, or possibly slightly more.

This apparatus has only just recently been introduced by Messrs. Maw, Son, and Thomson. It is given here in detail, because it carries out exactly the ideas which these pages are intended to describe and emphasize.

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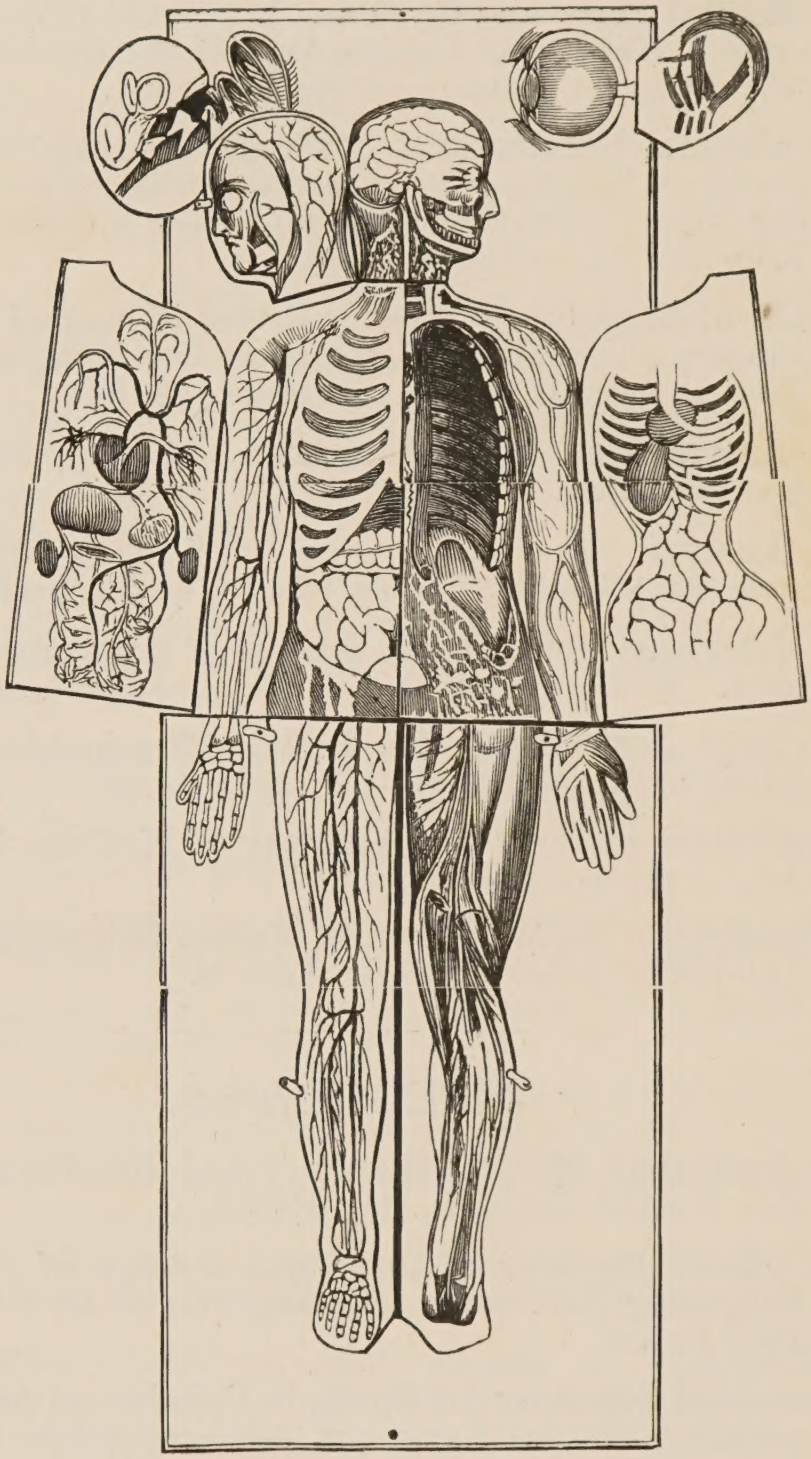

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